ating X-rays wherever they impinged, behaving in fact as kathode rays. (4) That in X-ray tubes, as usually exhausted, without excessive precautions for the drying of the gases, and the complete removal of residual hydrogen from the electrodes, the residual gas was in most cases hydrogen or water vapour.

In order to test the behaviour of other gases as compared with argon, similar experiments, in the same tubes, were made with dry air, with hydrogen, with oxygen, and with water vapour.

With dry oxygen and nitrogen, the absorption of the gas was very rapid at a pressure of one-tenth of a millimetre, if the electrodes were sufficiently heated. Although hydrogen was not observable and was presumably absent, the blackening of the tubes was very slight, and a much greater power could be applied than in the case of argon, without melting the electrodes.

With water vapour under the same conditions an X-ray vacuum could not be obtained (owing probably to the slowness of diffusion), unless the tube were considerably heated, either with a flame or by means of an excessive current. On allowing the tubes to cool under these circumstances, the vacuum improved very greatly, owing to absorption by the surface of the glass, and the discharge often refused to pass. Under steady conditions of running at a low temperature, there was no clear evidence of absorption of the water vapour, in spite of the drying tube on the pump.

With carefully dried hydrogen, under the same conditions, the process of exhausting the tubes with the mechanical pump was extremely rapid as compared with the other gases, owing to the greater velocity of diffusion of the lighter gas. With the smaller tubes, ten or twenty strokes were sufficient to give brilliant X-rays, starting in each case with a pressure of half a millimetre to a millimetre. There was no marked absorption at any stage of the vacuum, and no trace of sputtering of the electrodes. We expected to find some evidence of absorption by the electrodes or the platinum antikathode, but it is possible that these became saturated with gas very rapidly at an early stage, and ceased to absorb gas at an X-ray vacuum. We concluded that hydrogen was the most suitable gas to use in X-ray tubes, but it is possible that helium, being also a very light gas, might be equally good, if its inert or monatomic character does not lead to the disintegration of the electrodes in the same manner as in the case of argon.

If the great resistance to the passage of the discharge from the kathode to the gas in the case of argon, is dependent upon the monatomic nature of the gas, it might be expected that similar phenomena would be observed in the case of mercury. Some mercury vacuum tubes were therefore made in the form of inverted U tubes. The electrodes were liquid surfaces of mercury in each limb, to which connection was made by short pieces of platinum wire, which did not project above the surface of the mercury. These tubes were exhausted and boiled with an alternating discharge passing, until more than half the mercury had distilled over. They then presumably contained only mercury vapour. When cool, the two-inch spark discharge refused to pass at first, but if the tube were tilted for a moment, so as to expose the platinum wire, it appeared that sufficient gas was liberated to enable the discharge to pass without any difficulty. The tubes showed only the mercury spectrum. In the high resistance state, immediately after boiling, the kathode limb, with a larger spark coil, showed brilliant fluorescence and feeble X-rays. We concluded from these experiments that a very small trace of another gas was sufficient enormously to reduce the resistance of a mercury vapour tube, and that if the vapour could be obtained quite pure, it would possibly not conduct at all.

To verify more accurately the conditions of vacuum at which these phenomena occurred, the whole apparatus was subsequently connected to an automatic Sprengel mercury pump to which a McLeod gauge was attached. The pump and all its connections were carefully tested for leakage, and the drying tube was filled with fresh P_2O_5. We had found in previous experiments of a similar character made two or three years previously, that sulphuric acid, however carefully prepared, gave off appreciable quantities of water vapour, which would have been quite sufficient to vitiate these results.

Using a large coil and a slow mercury break, to avoid overheating the tubes, we found that fairly efficient X-rays were obtained in most of the tubes at an average vacuum of ·006 millimetre, if the tubes were exhausted in the ordinary way without taking special pains to remove the hydrogen. The H lines always showed faintly in the kathode light before this vacuum was reached. After using an alternating discharge to heat the electrodes, and carefully washing out the hydrogen as far as possible with argon, we found that the pressure corresponding to an X-ray vacuum gradually increased up to ·030 millimetre. Before letting the argon into the tube it was allowed to remain ten or fifteen minutes in contact with the fresh P_2O_5. On omitting this precaution and admitting the argon direct from a bulb containing an old sample of P_2O_5, which was beginning to deliquesce on the surface, it was necessary to raise the vacuum to ·015 millimetre before X-rays were produced. On the other hand, the sudden addition of dry argon at this stage up to a pressure of ·029, produced no change in the appearance of the tube. It is probable that we never succeeded *entirely* in eliminating the residual hydrogen, but we concluded from these and similar experiments that the presence of the argon by itself had little, if any, effect on the production of X-rays, since the amount present in the tube could be varied within wide limits.

We next endeavoured to ascertain at what degree of vacuum the apparent absorption of the argon previously observed could be reproduced. For this purpose we used two tubes of the double-focus pattern, and an alternating discharge. Taking the first tube slightly damp from the blowpipe, we exhausted it to one-fifth millimetre vacuum with the mechanical pump. The discharge was then turned on and adjusted to heat the tube and electrodes as much as possible with safety, *and the pump was not further worked*. Under these conditions the remaining water vapour was rapidly expelled and absorbed by the P_2O_5, the tube soon showed a brilliant hydrogen spectrum followed by green fluorescence, the antikathode became red hot, then cooled, and in fifteen minutes the discharge (20,000 volts) refused to pass. The tube was not appreciably blackened. On connecting to the direct current discharge, it gave brilliant X-rays. This case is interesting as showing that a very good vacuum may be obtained in these cases by simple absorption.

Dry argon was then admitted into the tube up to a pressure of 0·160 millimetre. At this pressure, in tubes three inches in diameter, with the direct or alternating current, the tube was filled with blue light, and gave a spectrum which was verified to be that of blue argon, without any visible trace of hydrogen or nitrogen. After running the direct and alternating current through the tube for half an hour, the tube became very black, but there was no change in the pressure as measured by the gauge. It should be remarked that in measuring these high vacua, the pump was usually stopped to allow time for the equalisation of the pressure throughout the apparatus. The alternating current in the primary of the coil was only 2·5 amperes with argon, whereas 4 amperes had been used with air. The latter current, if used with argon, would have melted up the kathodes. Finding no absorption at this pressure, the pump was started to run very slowly, and the same alternating discharge was continued. The sputtering of the electrodes rapidly increased, and at a vacuum of about one-tenth of a millimetre, the upper electrode suddenly melted off. Another tube was then tried, but met with a similar fate at the same degree of vacuum. The failure was so sudden that it was difficult to control the current in time. If the argon is actually absorbed, it is clear that the phenomenon depends upon very special conditions of temperature and discharge. It is possibly that the absorption is only apparent, and corresponds to a very sudden increase of resistance to the discharge at a particular degree of vacuum, such as occurs in an ordinary X-ray tube when the boundary of the dark space reaches the antikathode. With greater care, it may be possible to decide this point, but an unfortunate accident to our water mains prevented further investigations at the time. It is clear, however, that the behaviour of argon is peculiar, and it seems probable that most of the ordinary kathode ray phenomena are due to residual hydrogen.

THE ORIGIN OF THE EUROPEAN FAUNA.[1]

I HAVE endeavoured to show how the present fauna of Europe originated. For that purpose it was found advisable to commence the inquiry by the study of the past and present fauna of an island. The British Islands, and in particular Ireland, seemed to me most suitable for that object.

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[1] Summary of a paper by Dr. R. F. Scharf, read before the Royal Irish Academy. (Reprinted from the *Proceedings* of the Academy, 3 ser. vol. iv. No. 3, 1897.)

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The fauna of Ireland as well as the flora is found to consist mainly of two elements, one of which came from the north and the other from the south. In the fauna of Great Britain the same two elements occur, but there is, in addition, a third—an eastern one—chiefly confined to the eastern counties. The southern element contains animals which came originally from south-western, and others which migrated to the British Islands from the South and Central Europe. The former are confined to the south-western counties of England and Ireland, whilst the latter are chiefly found in the south-west of England, Wales, Ireland, and the west of Scotland. The northern element chiefly occurs in Scotland, the north of England, and the north and west of Ireland.

Though it may be admitted that a small percentage of the British fauna reached the British Islands by occasional means of dispersal, the bulk of it migrated on land. A land-connection must therefore have existed formerly between Great Britain and Ireland, and the continent of Europe.

The late Edward Forbes believed that the Lusitanian or south-western element in the Irish flora (it was not known at the time that there was also a similar fauna) came to Ireland in Miocene times and survived the Glacial Period on a now sunken land which lay to the south-west of that island. Almost all other authorities are convinced that both flora and fauna were entirely exterminated in Ireland during the Pleistocene Epoch, and that what exists there now, migrated to it after the Glacial Period.

A short statement of the general conclusions arrived at with regard to the geographical changes in Europe during later Tertiary times, and the chief migrations of animals now follows, so as to facilitate the comprehension of the principal arguments advanced in favour of the view that there were two distinct invasions of northern species, and that the Irish fauna is altogether pre-Glacial.

To judge from the range of the south-western European plants and animals in Ireland, it is evident, as Forbes suggested, that they came long before the other southern species or the northern ones. Last of all came the eastern or Siberian migrants. These never reached Ireland, but as we have such abundant evidence of the time of their arrival in Europe, the history of their migration is of great importance, since it furnishes us with a clue to the date of earlier migrations.

We have geological evidence that a vast migration proceeded from Siberia, and entered Europe between the Caspian and the Ural Mountains. A large number of mammals came with this Siberian invasion, and no fewer than twenty-nine species reached England, ten of which still inhabit Great Britain. There is no evidence that any of them ever lived in Ireland.

I have endeavoured to ascertain the causes of that migration and its geological date. Both Tcherski and Brandt, the two highest authorities, are of opinion that the present Siberian fauna lived in the country already in pre-Glacial times, and that, with the addition of some now extinct forms, such as the mammoth, it flourished as far north as the New Siberian Islands. Since the advent of the Glacial Period, the fauna is supposed to have very gradually retreated from these high northern latitudes, which are now almost uninhabitable.

Against these views it has been urged that, to some extent, the mammalian bones and carcases found in the New Siberian Islands, rest on a solid layer of ice, and that as this ice was probably formed during the Glacial Period, the migrations must have taken place in post-Glacial times. This presupposes an extraordinary amelioration of climate in Siberia, the effects of which certainly would have been felt in Europe, but of which we have no evidence.

There is geological evidence that a marine transgression took place in Northern Russia in early Pleistocene times, and that at the same time the united waters of the Caspian Sea and the Sea of Aral covered a large tract of the central parts of that country. It is supposed by some naturalists (and in favour of this view I have collected some additional facts) that the White Sea and this large inland sea were connected right across Russia, thus forming a barrier by means of which the Siberian fauna was prevented from migrating to Europe. It is also suggested that the whole of the continental boulder-clay is a marine deposit, and that its maximum southward extension approximately marks the shores of a north European ocean.

In support of this view are quoted a number of Caspian species which must have come from the Arctic Ocean, and the fact of the occurrence of *Dreyssensia polymorpha*, in the lower and not in the upper continental boulder-clay, thus proving that a migration took place in both directions.

As all the deposits in continental Europe, containing remains of Siberian mammals, are of a later age than the lower boulder-clay, it seemed to me that the connection between the Aralo-Caspian and the White Sea must have ceased to exist during and after the Interglacial phase of the Glacial Period, which would also explain the absence of Dreyssensia in the more recent beds. The Siberian fauna probably began to pour into Europe immediately after the deposition of the lower continental boulder-clay. But since the first Siberian mammals made their appearance in England, during the deposition of the Forest-bed, the British newer Pliocene beds must be contemporaneous with this boulder-clay. Further proof of this will be mentioned later on.

Some further evidence is now given in favour of the marine origin of the boulder-clay, and the causes of the absence of marine shells in the Russian deposits are explained.

We have geological proofs that the Siberian fauna migrated to Europe on a tract of country known as the "Tchernosjen" or black earth of Russia, and that this originated from the decay of grass which grew there during long ages. This fauna then invaded Central Europe and Great Britain. In France its further progress was arrested by the river Garonne. England and France must therefore have been connected; whilst the absence of deposits containing Siberian mammals from Scandinavia proved that it was separated from the continent.

The Northern or Arctic element in the Irish fauna must have come directly from the north. It is more or less confined to the northern and western parts of Ireland, and forms a large proportion of the fauna of Scotland and Scandinavia. It suggests that a land-connection between the latter and the British Islands must have existed. The present and past range of the Arctic hare, the reindeer, and the stoat are discussed in detail to show that such a connection actually united the two countries. Reference is also made to the North American species occurring in Ireland which belong to the same migration.

The evidences in favour of a former land-connection between Scandinavia and Greenland *via* Spitsbergen are now reviewed.

It is suggested that the American marine mollusca which have been discovered in late Tertiary deposits of the east coast of England reached that coast, not from the Atlantic, but from the Arctic Ocean by means of the sea which extended from the White Sea to the German Ocean.

The migration of terrestrial animals and plants from this ancient northern land southward took place chiefly during the deposition of the newer English crags, and of the continental lower boulder-clay, that is to say, before the Siberian migrants set foot on British soil.

The southern migration to the British Islands commenced earlier than either the Arctic or the Siberian. Numerous instances are quoted to prove that the southern fauna is composed of species of south-western and of southern and Central European as well as of Asiatic origin.

In connection with the origin of the Red Deer, the nature of the geographical changes which the Mediterranean basin has undergone during later Tertiary times are now discussed.

I have endeavoured to show that Ireland was separated from England at the time while the migration from Southern and Central Europe was in progress. The contradictory evidence from fossil sources as to the climate prevailing at that time in the British Islands are there now discussed.

The orgin and nature of the Glacial Period is so intimately connected with these faunistic problems, that it has been thought advisable to devote a short chapter to this important era in the life of the direct ancestors of our animals. The prevailing opinions as to temperature and general atmospheric conditions during the period are reviewed in connection with the questions as to the possibility of a survival of the terrestrial fauna and flora chiefly in the British Islands. The British Pleistocene fauna does not indicate the prevalence of Arctic conditions—neither does the flora.

This fact certainly supports the view formerly held by geologists that the phenomena in Northern Europe, now attributed to land-ice, have been produced by sea with floating icebergs, under conditions somewhat comparable to those at present obtaining in Tierra del Fuego. A succinct statement of my views on the Glacial Period and the geographical features of Europe at the time—as derived from a study of the European fauna and of its origin—concludes this memoir.

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